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(54) Filter arrangement.

(57) A first (R_1) and a second (R_2) resistor are arranged in series between an input terminal (5) for receiving an input voltage (v_i) and the input (2) of an amplifier (1). The amplifier (1) comprises a transistor (T_1) whose base is coupled to the input (2), whose emitter is coupled to a first output (3) and via a current source (I_1) to earth, and whose collector is coupled to a second output (4) and via a third resistor (R_3) to the positive power-supply terminal. A first capacitor (C_1) is arranged between the junction point (6) between the first resistor (R_1) and the second resistor (R_2) and a second capacitor (C_2) is arranged between the input (2) and earth. A signal having a second-order low-pass characteristic is taken from the first output (3) and a signal having a second-order high-pass characteristic is taken from the second output (4).

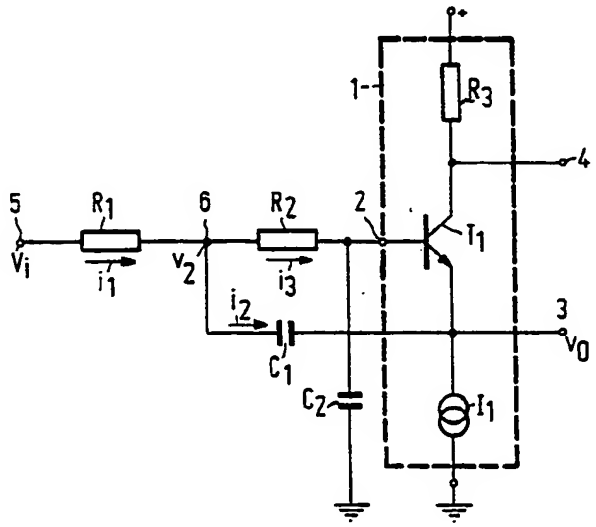

FIG.1

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Filter arrangement.

The invention relates to a filter arrangement comprising at least a first and a second resistor arranged in series between an input terminal for receiving an input signal and an input of an amplifier comprising a transistor whose base is coupled to the input and whose emitter is coupled to a first power-supply terminal by means of a current source and to a first output for a first output signal, which first output is coupled to the junction point between the first resistor and the second resistor by a first capacitor and which input is coupled to a power-supply terminal by a second capacitor.

Such a filter arrangement is suitable for general purpose and in particular for use in a fully integrated television receiver.

Such a filter arrangement is known inter alia from the book "Halbleiter Schaltungstechnik" by Tietze and Schenk, 5th edition, 1980, pp. 295-296. This filter arrangement is generally referred to as a Sallen-Key filter and constitutes a second-order low-pass filter arrangement, in which the output signal is taken from the emitter of the transistor. The collector of this transistor is connected directly to the positive power-supply terminal.

In addition to a low-frequency signal with a second-order low-pass characteristic many uses also require a high-frequency signal with a second-order high-pass characteristic. For this purpose a separate second-order high-pass filter may be employed, but this results in the number of components being doubled and an increase in power consumption.

European Patent Specification 52.117 describes a filter arrangement comprising a first transistor whose collector is connected to a reference voltage via a capacitor and to the emitter of a second transistor whose base is also connected to said reference voltage and whose collector is connected to a bias current source and to a second capacitor and the base of the first transistor.

A table indicates whether the voltages and currents at various points in this filter arrangement have a low-pass, a high-pass or a band-pass characteristic for each of the possible inputs to which an input signal can be applied. This table indicates that in two cases both a signal with a high-pass characteristic and a signal with a low-pass characteristic are obtained. If an input voltage is applied to the emitter of the first transistor, the table shows that a voltage having a second-order low-pass characteristic appears on the base of this transistor and the collector current of the first resistor constitutes a second-order high-pass signal current. However, as is indicated in description of said Patent Specification this signal current is not available for further use. Thus, when the emitter is driven this does not yield both a signal having a low-pass characteristic and a signal having a high-pass characteristic. If an input voltage is applied to the base of the second transistor said table indicates that a voltage having a second-order low-pass characteristic is obtained on the emitter of the second transistor and the collector current of the second transistor constitutes a signal current having a second-order high-pass characteristic. However, to enable this signal current to be utilised additional means are required, for example a diode in the collector line of the second transistor arranged in parallel with a further transistor. The arrangement then comprises a comparatively large number of components.

Therefore, it is the object of the invention to provide a filter arrangement comprising a minimal number of components and enabling both an output signal having a second-order low-pass characteristic and an output signal having a second-order high-pass characteristic to be obtained. According to the invention a filter arrangement as defined in the opening paragraph is characterized in that the collector of the transistor is coupled to a second output for a second output signal. The invention is based on the recognition of the fact that the current through the first capacitor has a second-order high-pass characteristic. This current is applied to the emitter of the transistor, so that almost the full current flows also into the collector of this transistor. The collector current is now used in order to generate a second output signal. The filter arrangement comprises only one transistor. so that it is constructed by means of a minimal number of components and can be integrated on a very small chip-area. Moreover, the filter arrangement requires only a very low supply voltage and has a low current consumption.

A first embodiment of a filter arrangement in accordance with the invention may be characterized in that the collector is coupled to a second power-supply terminal by a third resistor. The signal voltage available across the third resistor then constitutes the output signal having a second-order high-pass characteristic.

A second embodiment of a filter arrangement in accordance with the invention may be characterized in that the amplifier circuit comprises a second transistor having its base coupled to the base of the first transistor, having its emitter coupled to the first power-supply terminal by means of a second current soruce identical to the first current source, and having its collector coupled to the second power-supply terminal by a fourth resistor identical to the first resistor and to a third output, the second output signal being available

between the second output and the third output. As a result of these steps, undesired voltage components in the output voltage as a result of supply-voltage variations and bias-current variations are largely suppressed. This greatly improves the rejection of the signal voltage in the so-called stop band.

A third embodiment of a filter arrangement in accordance with the invention may be characterized in that the collector of the transistor is coupled to a second power-supply terminal by means of a second current source which is substantially identical to the first current source. The second current source compensates for the current from the first current source, so that the signal current flowing through the first capacitor can be taken directly from the second output.

A fourth embodiment of a filter arrangement in accordance with the invention may be characterized in that the second capacitor is coupled to a power-supply terminal by a fifth resistor and to an output for a third output signal. The current through the second capacitor has a first-order band-pass characteristic. This current is utilized by arranging a resistor in series with the second capacitor, across which resistor an output voltage having a first-order band-pass characteristic is available.

Embodiments of the invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which

Fig. 1 shows a first embodiment of a filter arrangement in accordance with the invention,

Fig. 2 shows a second embodiment of a filter arrangement in accordance with the invention,

Fig. 3 shows a third embodiment of a filter arrangement in accordance with the invention, and

Fig. 4 shows a fourth embodiment of a filter arrangement in accordance with the invention.

Fig. 1 shows the simplest embodiment of a filter arrangement in accordance with the invention. The arrangement comprises an amplifier 1 which in the present embodiment comprises a transistor T_1 whose base is coupled to the input 2 of the amplifier, whose emitter is coupled to a first output 3 and via current source I_1 to the negative power-supply terminal, in the present case earth, and whose collector is coupled to a second output 4 and via a resistor R_3 to the positive power-supply terminal. The series arrangement of two resistors R_1 and R_2 is connected between a signal input 5 and the input 2 of the amplifier 1. The junction point 6 between these resistors is connected to the first output 3 by a first capacitor C_1. The input 2 of the amplifier 1 is coupled to the negative power-supply terminal by a capacitor C_2. It is to be noted that this capacitor may alternatively be coupled to the positive power-supply terminal.

The arrangement without the resistor R_4 and the output 4, in which the collector of the transistor T_1 is connected directly to the positive power-supply terminal, is a second-order low-pass filter arrangement known per se, in which the output signal is taken from the emitter of the transistor T_1. In brief, this known arrangement operates as follows. For low frequencies the reactance of the capacitor C_1 and C_2 is so large that these capacitors do not affect the operation of the arrangement. The signal voltage on the output 3 is then substantially equal to that on the input 5. At increasing frequency the reactance of the capacitors C_1 and C_2 decreases. Under the influence of the capacitor C_2 the arrangement then behaves as a first-order RC filter, the signal voltage on the output 3 having a roll-off of 6dB/octave. At increasing frequency the signal voltage on the output 3 becomes so small that this output may be regarded as a virtual earth. As a result of this, the capacitor C_1 is connected to earth. The circuit then behaves as a second-order RC filter, the signal voltage on the output 3 having a roll-off of substantially 12 dB/octave.

The transfer function to the output 3 of the circuit arrangement can be derived as follows. If for an input voltage v_i and an output voltage v_o the current through the resistor R_1 is i_1, the current through the capacitor C_1 is i_2, and the current through the resistor R_2 is i_3, the following equation is valid:

$$i_1 = i_2 + i_3 \qquad (1)$$

If the voltage on the junction point 6 between the resis tors R_1 and R_2 is v_1 and it is also assumed that the voltage on the input 2 is v_o, equation 1 may be written as

$$\frac{v_i - v_1}{R_1} = (v_1 - v_o)\, pC_1 + \frac{(v_1 - v_o)}{R_2} \qquad (2)$$

where p is the complex frequency. If the base current of the transistor T_1 is ignored, the current i_3 flows fully through the capacitor C_2, so that

$$\frac{v_1 - v_o}{R_2} = v_o\, pC_2 \text{ or } v_1 = (pC_2R_2+1)v_o \quad (3)$$

Inserted in equation 2, it follows that the transfer function is

$$\frac{v_o}{v_i} = \frac{1}{p^2T_1T_2 + p(T_2+R_1C_2) + 1} = \frac{1}{N} \quad (4)$$

where $T_1 = R_1C_1$ and $T_2 = R_2C_2$.
Equation (4) is characteristic of the transfer function of a second-order low-pass filter arrangement.

The current through the capacitor C_1 complies with:

$i_2 = (v_1 - v_o)pC_1 = p^2C_1T_2V_o$ (5)

This current and the input voltage are related as follows:

$$\frac{i_2}{v_i} = \frac{p^2C_1T_2}{N} \quad (6)$$

This equation is characteristic of the transfer function of a second-order high-pass filter arrangement. The invention is based on the recognition of the fact that the current i_2 is a signal having a second-order high-pass characteristic. In accordance with the invention this current is utilized to derive a second-order high-pass-filtered output signal in addition to a second-order low-pass-filtered output signal by means of the same filter arrangement. The current i_2 is injected at the emitter of the transistor T_1 and also flows into the collector of this transistor, when the base current is ignored. In this embodiment the collector is coupled to the positive power-supply terminal via a resistor R_3. Across this resistor this yields a signal voltage which is given by

$$\frac{v_o'}{v_i} = \frac{p^2C_1T_2R_3}{N} \quad (7)$$

The voltage v_o' is available on the output 4.

Fig. 2 shows a second embodiment of a filter arrangement in accordance with the invention, in which identical parts bear the same reference numerals as in Fig. 1. A transistor T_2 is arranged in parallel with the transistor T_1 and has its emitter coupled to earth via a current source I_2 identical to the current source I_1 and its collector coupled to the positive power-supply terminal via a resistor R_4 identical to the resistor R_3. The collector of the transistor T_2 is also coupled to an output 7. The output voltage is now differentially taken from the outputs 4 and 7. This has the following advantage. Supply-voltage variations give rise to variations in the current through the transistor T_1 owing to retroaction. Since the current source I_1 has a finite output impedance low-frequency voltage variations on the emitter of the transistor T_2 also give rise to variations in the current through the transistor T_1. These two current variations produce undesired voltages on the output 4, as a result of which the suppression of supply voltage variations and the stop-band rejection at the output 4 are comparatively small. The undesired voltages appearing on the collector of the transistor T_1 also appear on the collector of the transistor T_2. These undesired voltages are suppressed strongly by differential take-off of the high-pass filtered signal.

Fig. 3 shows a third embodiment of a filter arrangement in accordance with the invention, in which identical parts bear the same reference numerals as in Fig. 1. In this embodiment the collector of the transistor T_1 is not coupled to the positive power-supply terminal via a resistor but via a current source I_3. The current source I_3 compensates for the current from the current source I_1. The signal current i_2 (see

equation 6) is then available directly on the output 4.

Fig. 4 shows a fourth embodiment of a filter arrangement in accordance with the invention, in which identical parts bear the same reference numerals as in Fig. 1. This embodiment differs from that shown in Fig. 1 in that a resistor R_5 is arranged in series with the capacitor C_2. The current through the capacitor C_2 complies with:

$i_3 = V_o pC_2$ (8)

so that the following relationship exists between this current and the input voltage:

$$\frac{i_3}{v_i} = \frac{pC_2}{N} \qquad (9)$$

This equation is characteristic of the transfer function of a first-order band-pass filter arrangement. The current i_3 is now converted into a voltage across the resistor R_5, which voltage can be taken from the output 8. This voltage is then equal to:

$$\frac{v_o'}{v_i} = \frac{pR_5C_2}{N} \qquad (10)$$

It is to be noted that is the capacitor C_2 is connected to the positive power-supply terminal, the resistor R_5 is also connected to the positive power-supply terminal.

The invention is not limited to the embodiments shown. Within the scope of the invention many variants are conceivable to those skilled in the art. For example, in the embodiments shown the amplifier comprises only one transistor. However, the amplifier may alternatively comprise a Darlington transistor. Further, in the embodiment shown in Fig. 1 the high-frequency signal is available on the output 4 relative to the positive supply voltage. However, it is alternatively possible to first process the collector current of the transistor T_1 in a current-mirror circuit, after which it is converted into a voltage across the resistor R_3, so that on the output 4 the signal is available relative to earth.

Claims

1. A filter arrangement comprising at least a first and a second resistor arranged in series between an input terminal for receiving an input signal and an input of an amplifier comprising a transistor whose base is coupled to the input and whose emitter is coupled to a first power-supply terminal by means of a current source and to a first output for a first output signal, which first output is coupled to the junction point between the first resistor and the second resistor by a first capacitor and which input is coupled to a power-supply terminal by a second capacitor, characterized in that the collector of the transistor is coupled to a second output for a second output signal.

2. A filter arrangement as claimed in Claim 1, characterized in that the collector is coupled to a second power-supply terminal by a third resistor.

3. A filter arrangement as claimed in Claim 2, characterized in that the amplifier circuit comprises a second transistor having its base coupled to the base of the first transistor, having its emitter coupled to the first power-supply terminal by means of a second current source identical to the first current source, and having its collector coupled to the second power-supply terminal by a fourth resistor identical to the first resistor and to a third output, the second output signal being available between the second output and the third output.

4. A filter arrangement as claimed in Claim 1, characterized in that the collector of the transistor is coupled to a second power-supply terminal by means of a second current source which is substantially identical to the first current soruce.

5. A filter arrangement as claimed in Claim 1, 2, 3 or 4, characterized in that the second capacitor is coupled to a power-supply terminal by a fifth resistor and to an output for a third output signal.

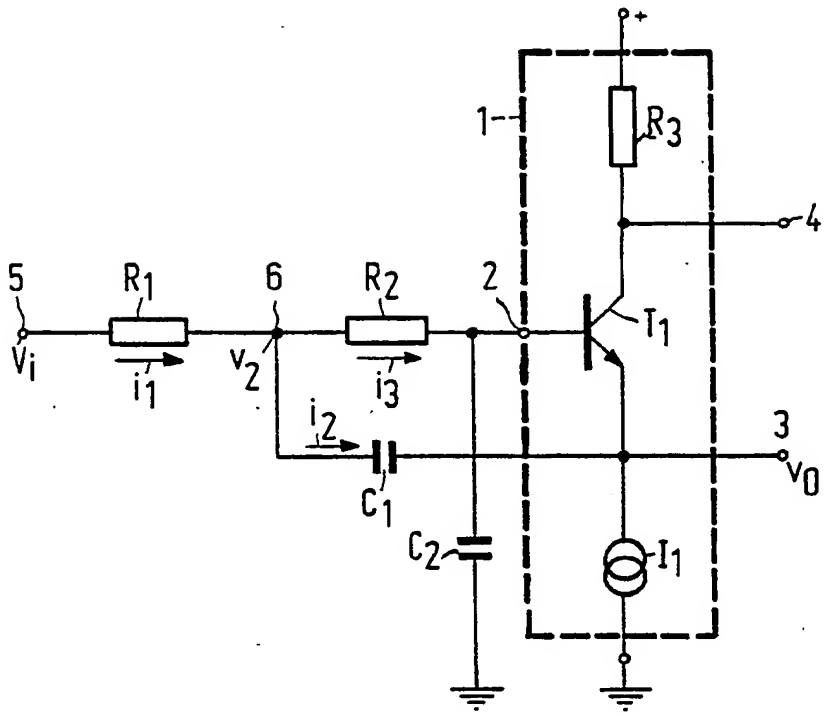

FIG.1

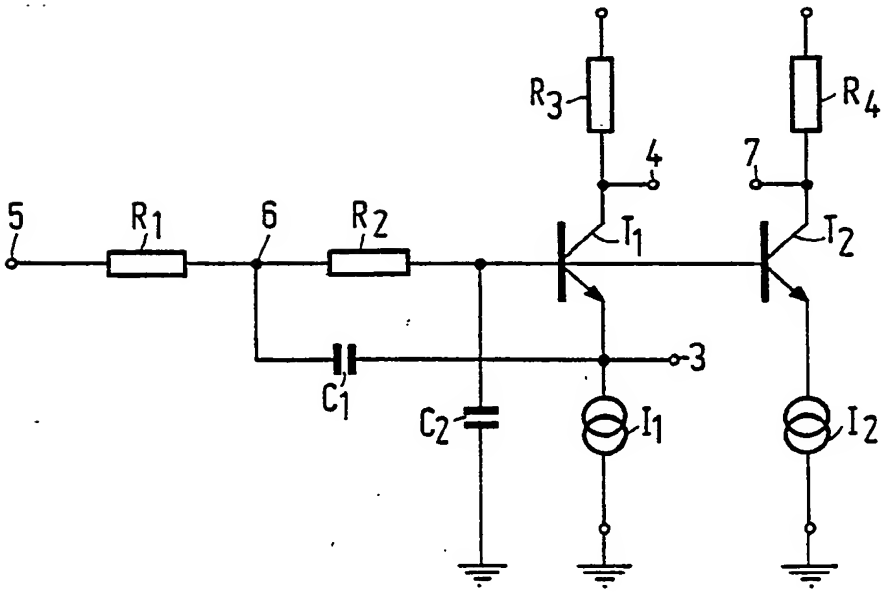

FIG.2

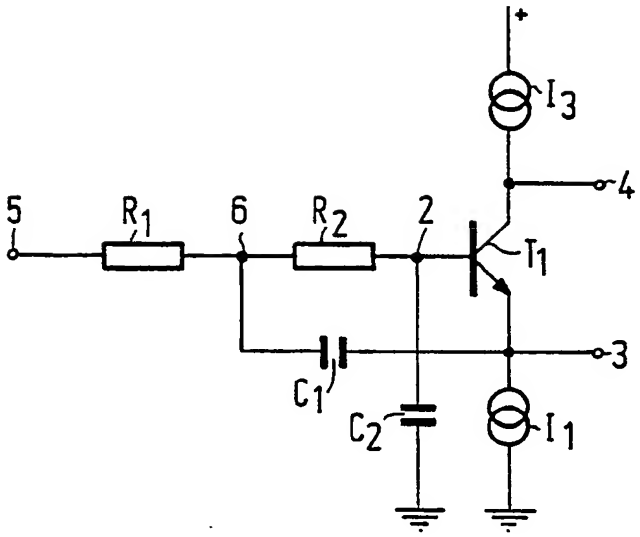

FIG.3

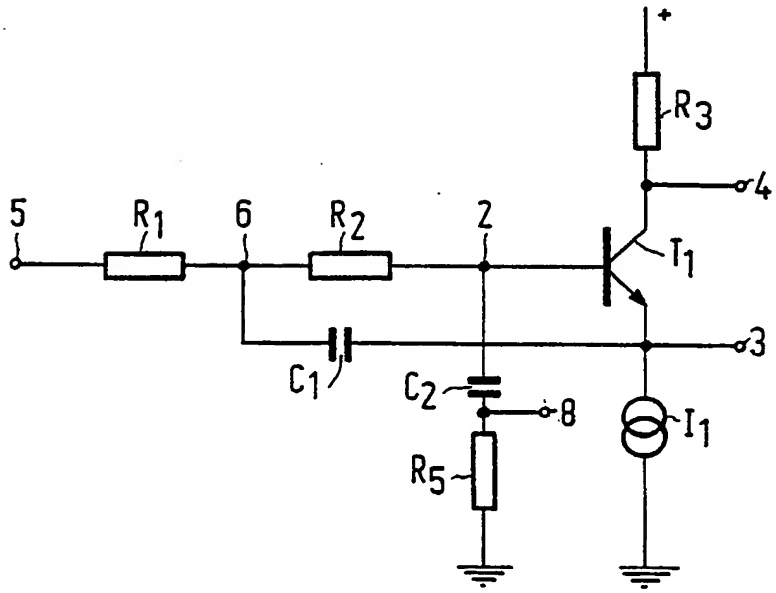

FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 20 2460

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-3 501 709 (D. UETRECHT) * Whole document * ---	1	H 03 H 11/34 H 03 H 11/12
A	THE ELECTRONIC ENGINEER, vol. 27, no. 10, October 1968, pages 57-64; R. KINCAID: "RC filter design by the numbers" * Figure 1 * -----	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 03 H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10-03-1988	DECONINCK E.F.V.

CATEGORY OF CITED DOCUMENTS

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